Training and Support

2017-2018 *FIRST*® Tech Challenge
Using Vuforia VuMarks

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FOR INSPIRATION & RECOGNITION OF SCIENCE & TECHNOLOGY

Revision History		
Revision	**Date**	**Description**
1.0	09/09/2017	Initial Release

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1 Introduction

1.1 What is FIRST® Tech Challenge?

FIRST Tech Challenge is a student-centered program that focuses on giving students a unique and stimulating experience. Each year, teams engage in a new Game where they design, build, test, and program autonomous and driver operated robots that must perform a series of tasks.

They also cultivate life skills such as:

- Planning, brainstorming, and creative problem-solving.
- Research and technical skills.
- Collaboration and teamwork.
- Appreciating differences and respecting the ideas and contributions of others.

To learn more about *FIRST* Tech Challenge and other *FIRST*® Programs, visit www.firstinspires.org.

FIRST Tech Challenge is MORE THAN ROBOTS℠! **While competing, students develop personal and professional skills they will be able to rely on throughout their life.**

1.2 FIRST Tech Challenge Core Values

FIRST asks everyone who takes part in *FIRST* Tech Challenge to uphold the following values:

- We display *Gracious Professionalism*® with everyone we engage with and in everything we do.
- We act with integrity.
- We have fun.
- We are a welcoming community of students, mentors, and volunteers.
- What we learn is more important than what we win.
- We respect each other and celebrate our diversity.
- Students and adults work together to find solutions to challenges.
- We honor the spirit of friendly competition.
- We behave with courtesy and compassion for others always.
- We act as ambassadors for *FIRST* and *FIRST* Tech Challenge.
- We inspire others to adopt these values.

2 *Gracious Professionalism*®

FIRST uses this term to describe our programs' intent and is shared with all young people engaging in *FIRST* programs. At *FIRST*, team members help other team members, but they also help other teams.

Gracious Professionalism® is not clearly defined for a reason. It has different meanings to everyone.

Some possible meanings of *Gracious Professionalism* include:

- Gracious attitudes and behaviors are win-win.
- Gracious folks respect others and let that respect show in their actions.
- Gracious Professionals make valued contributions in a way that is pleasing to others and to themselves.

In *FIRST*, *Gracious Professionalism* teaches teams and student participants:

An example of *Gracious Professionalism* is patiently listening to a team's question and providing support despite having several pressing things to do on the day of the event.

- Learn to be strong competitors, but also treat one another with respect and kindness in the process.
- Avoid leaving anyone feeling as if they are excluded or unappreciated.
- Knowledge, pride and empathy should be comfortably and genuinely blended.

In the end, *Gracious Professionalism*® is part of everyday life. When professionals use their knowledge in a graciously and individuals act with integrity and sensitivity, everyone wins, and society benefits.

Watch Dr. Woodie Flowers explain *Gracious Professionalism* in this short video.

2.1 Gracious Professionalism for Volunteers

It is a good idea to spend time going over this concept with volunteers. Provide volunteers with real-life examples of *Gracious Professionalism* in practice before, during, and after the event and recognize great *Gracious Professionalism* when you see it in action!

3 Youth Protection Program

The *FIRST* YPP sets minimum standards recommended for all *FIRST* activities. Adults working in *FIRST* programs must be knowledgeable of the standards set by the *FIRST* YPP, as well as those set by the school or organization hosting their team.

3.1 Youth Protection Expectations and Guidelines

Coaches and mentors should read and follow the FIRST Youth Protection Program guide. Anything labeled as required is mandatory in the United States and Canada, and cannot be waived without approval from the *FIRST* Youth Protection Department. *FIRST* recommends that the standards set forth in the *FIRST* Youth Protection Program guide be applied outside of the United States and Canada to the extent possible. At a minimum, local regulations regarding youth protection must be complied with.

Most up to date forms are available here: http://firstinspires.org/resource-library/youth-protection-policy

The US Screening process, the Canadian Screen process, Frequently Asked Questions (FAQ), and additional information are on the *FIRST* Youth Protection Program Website: http://firstinspires.org/resource-library/youth-protection-policy

3.2 NOTICE OF NON-DISCRIMINATION

For Inspiration and Recognition of Science and Technology (*FIRST*®) does not discriminate based on race, color, national origin, sex, disability, age, status as a veteran who served in the military, religion, gender, gender identity, or gender expression in its programs and activities.

Keep updated at: http://www.firstinspires.org/about/legal-notices

4 What is a VuMark?

The 2017-2018 *FIRST* Tech Challenge game includes special vision targets that contain secret clues that can be used to score extra points during the autonomous portion of a match. These special vision targets are known as *VuMarks.* The VuMarks use PTC's Vuforia computer vision technology to encode hidden information within each picture. This information isn't easily noticeable to the casual human observer. However, the *FIRST* Tech Challenge software for the 2017-2018 season includes special functions that let a robot read the VuMarks using the Robot Controller's built-in camera.

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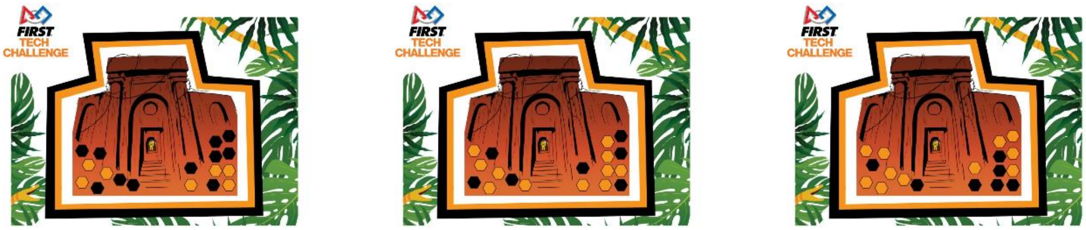


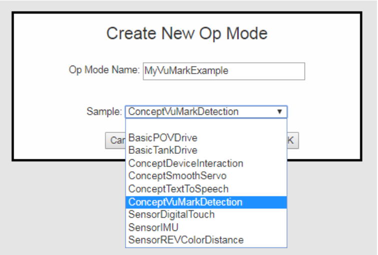
Figure 1 - The VuMarks represent "LEFT", "CENTER", and "RIGHT" values.

The three images shown above represent "LEFT", "CENTER" and "RIGHT" values. If, for example, the "LEFT" image is displayed during a match, then the robots should try and score their preloaded game elements into the leftmost goal during the autonomous portion of that match.

Note that the VuMark-related features of the software are only available with ***version 3.3*** of the FTC software (Robot Controller and Driver Station) and higher.

5 Example Blocks VuMark Op Mode

Version 3.3 and higher of the FTC Robot Controller app includes a sample op mode that demonstrates how to check for VuMarks and extract the hidden information when a VuMark is identified. To create an op mode based on this VuMark Example, click on the "Create New Op Mode" button, specify a name for your new op mode, and in the "Sample:" drop down list, select the item named "ConceptVuMarkDetection".



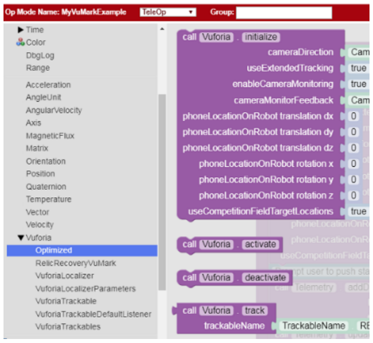
Create New Op Mode

Op Mode Name: MyVuMarkExample

Sample: ConceptVuMarkDetection

Figure 2 - Select "ConceptVuMarkDetection" from the "Sample" drop down list.

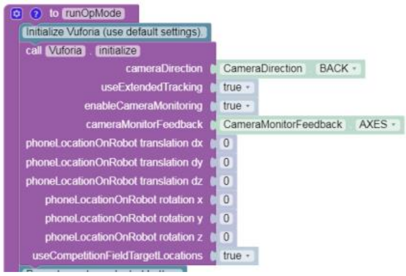
When you first look at the newly created example VuMark op mode, you will see Vuforia-specific blocks included in the op mode. The Vuforia-specific blocks that are used in this example op mode can be found in the "Optimized" subcategory of the "Vuforia" collection of programming blocks. Note that the "Vuforia" collection is a subcategory of the "Utilities" collection of blocks:



```
call Vuforia . initialize
                      cameraDirection  Cam
                  useExtendedTracking  true
               enableCameraMonitoring  true
                cameraMonitorFeedback  Cam
phoneLocationOnRobot translation dx  0
phoneLocationOnRobot translation dy  0
phoneLocationOnRobot translation dz  0
    phoneLocationOnRobot rotation x  0
    phoneLocationOnRobot rotation y  0
    phoneLocationOnRobot rotation z  0
 useCompetitionFieldTargetLocations  true

call Vuforia . activate

call Vuforia . deactivate

call Vuforia . track
          trackableName  TrackableName  RE
```

Figure 3 – The Vuforia-related blocks can be found in the "Optimized" subcategory in the Blocks Programming palette.

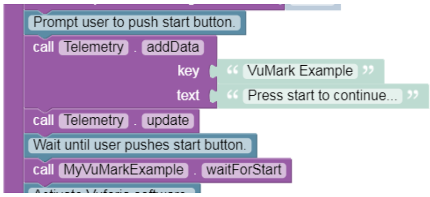
Let's step through the blocks in the example op mode. The op mode first uses the block "call Vuforia.initialize" to initialize the Vuforia software. Note that the default values for the initialization parameters are used.



```
to runOpMode
  Initialize Vuforia (use default settings).
  call Vuforia . initialize
                        cameraDirection  CameraDirection . BACK
                    useExtendedTracking  true
                 enableCameraMonitoring  true
                  cameraMonitorFeedback  CameraMonitorFeedback . AXES
  phoneLocationOnRobot translation dx  0
  phoneLocationOnRobot translation dy  0
  phoneLocationOnRobot translation dz  0
      phoneLocationOnRobot rotation x  0
      phoneLocationOnRobot rotation y  0
      phoneLocationOnRobot rotation z  0
   useCompetitionFieldTargetLocations  true
```

Figure 4 – Initialize the Vuforia software (use default parameter values).

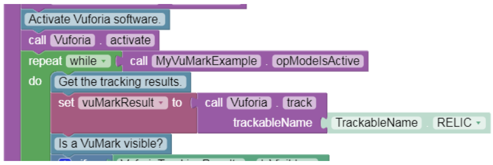
The op mode then prompts the user to push the start button to continue and it waits to receive a start command from the Driver Station.



```
Prompt user to push start button.
call Telemetry . addData
                 key  "VuMark Example"
                text  "Press start to continue..."
call Telemetry . update
Wait until user pushes start button.
call MyVuMarkExample . waitForStart
```

Figure 5 - Prompt user to push start button.

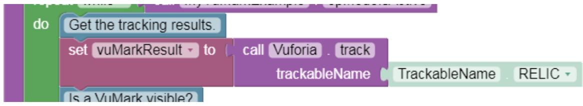
After the op mode receives the start command, it will activate the vision tracking mechanism. It then will enter a while loop and will continue to loop as long as the op mode is running.



```
Activate Vuforia software.
call Vuforia . activate
repeat while  call MyVuMarkExample . opModeIsActive
do  Get the tracking results.
    set vuMarkResult to  call Vuforia . track
                                 trackableName  TrackableName . RELIC
    Is a VuMark visible?
```

Figure 6 - The op mode activates the tracking mechanism and starts the main op mode loop.

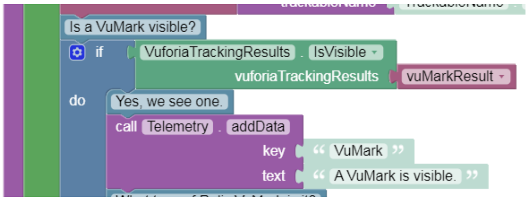
At the start of the loop, the op mode will receive tracking information from the Vuforia system:



```
do  Get the tracking results.
    set vuMarkResult to  call Vuforia . track
                                 trackableName  TrackableName . RELIC
    Is a VuMark visible?
```

Figure 7 - The op mode receives tracking information from the Vuforia system.

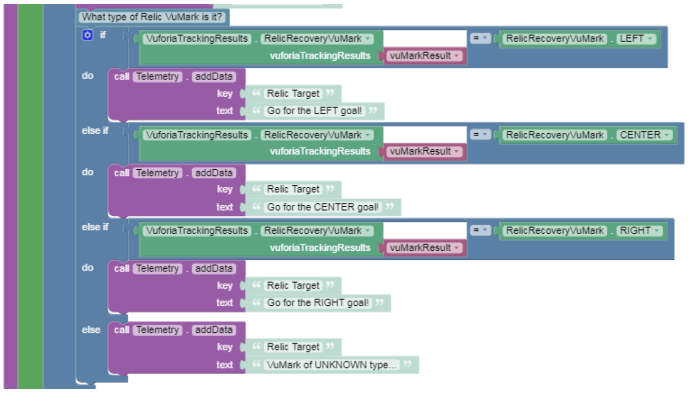
After the op mode has received the tracking results from the Vuforia system, it checks to see if a VuMark is currently visible,



```
Is a VuMark visible?
if   VuforiaTrackingResults . IsVisible
                    vuforiaTrackingResults   vuMarkResult
do   Yes, we see one.
     call Telemetry . addData
                      key   " VuMark "
                      text  " A VuMark is visible. "
```

Figure 8 - Is a VuMark Visible?

If a VuMark is visible, the op mode will alert the user with a telemetry statement. If a VuMark is visible, the op mode will also attempt to identify which VuMark it is.

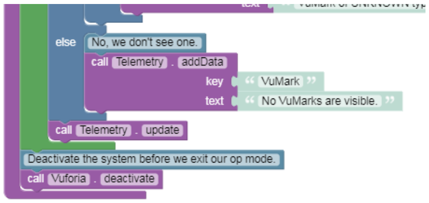


```
What type of Relic VuMark is it?
if       VuforiaTrackingResults . RelicRecoveryVuMark        = RelicRecoveryVuMark . LEFT
                      vuforiaTrackingResults   vuMarkResult
do       call Telemetry . addData
                           key   " Relic Target "
                           text  " Go for the LEFT goal! "
else if  VuforiaTrackingResults . RelicRecoveryVuMark        = RelicRecoveryVuMark . CENTER
                      vuforiaTrackingResults   vuMarkResult
do       call Telemetry . addData
                           key   " Relic Target "
                           text  " Go for the CENTER goal! "
else if  VuforiaTrackingResults . RelicRecoveryVuMark        = RelicRecoveryVuMark . RIGHT
                      vuforiaTrackingResults   vuMarkResult
do       call Telemetry . addData
                           key   " Relic Target "
                           text  " Go for the RIGHT goal! "
else     call Telemetry . addData
                           key   " Relic Target "
                           text  " VuMark of UNKNOWN type... "
```

Figure 9 - The op mode checks to see which VuMark was detected.

If the target is identified, the op mode uses a telemetry statement to inform the user which target (LEFT, CENTER or RIGHT) was detected. Otherwise it tells the user that the VuMark is of an unknown type.

If a VuMark was not visible, the op mode sends a message to Driver Station to inform the user that no VuMarks are currently visible.



```
else  No, we don't see one.
      call Telemetry . addData
                        key   " VuMark "
                        text  " No VuMarks are visible. "
call Telemetry . update
Deactivate the system before we exit our op mode.
call Vuforia . deactivate
```

Figure 10 - The Op Mode deactivates Vuforia before it exits.

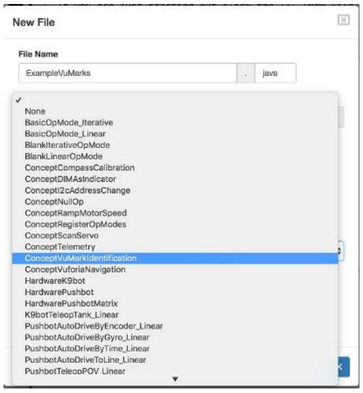
When a user presses the stop button on the Driver Station, the op mode will stop its main program loop. Before it exits, the op mode will deactivate the Vuforia software.

6 Example Java VuMark Op Mode

If you are a Java Programmer, there is a sample op mode that demonstrates how to check for and identify VuMarks in a Java op mode.

The sample op mode is named “ConceptVuMarkIdentification” and it’s available through both the FTC OnBot Java Programming Tool user interface, and in the ftc_app Android Studio project.

If you are an OnBot Java user, when you create a new op mode, you should be able to see the item “ConceptVuMarkIdentification” listed in the dropdown list of the sample op mode control. Select this example as you create your new file.

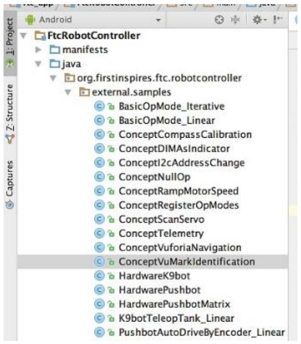


New File

File Name: ExampleVuMarks . java

Figure 11 - ConceptVuMarkIdentification is available through the OnBot Java UI.

If you are an Android Studio user, you can find a copy of the ConceptVuMarkIdentification sample op mode in the external.samples subfolder of the ftc_app Android project. Copy this op mode to your teamcode op mode directory and comment out the @Disabled annotation to enable this op mode.



Let’s take a look at the key statements in the example source code. In the class definition for your op mode there is a member variable of type VuforiaLocalizer:

```
/**
 * {@link #vuforia} is the variable we will use to store our instance of the Vuforia
 * localization engine.
 */
VuforiaLocalizer vuforia;
```

This variable will be a reference to the instance of the Vuforia localization/tracking engine.

In the method **runOpMode()** the first two statements are used to configure the system to display a camera monitor window on the FTC Robot Controller app, as the op mode is running. The first statement (see below) gets the id of the Android view that will be used to display camera output as the op mode is running. The second statement creates a variable called “parameters” that will hold the parameters that will be used to initialize the Vuforia engine.

```
int cameraMonitorViewId = hardwareMap.appContext.getResources().getIdentifier("cameraMonitorViewId", "id",
hardwareMap.appContext.getPackageName());
VuforiaLocalizer.Parameters parameters = new VuforiaLocalizer.Parameters(cameraMonitorViewId);
```

Note that if you want to disable the camera monitor window (for example, to use less CPU and battery power on your smartphone) you can invoke the VuforiaLocalizer.Parameters() constructor without any arguments.

In the next statement, the user must provide a Vuforia developer license key in order to unlock the Vuforia-related functions. The sample op mode does **not** include a valid license key. You must provide your own key to enable the Vuforia functions.

```
parameters.vuforiaLicenseKey = "ATsODcD/////AAAAAVw21R...d45oGpdljdOh5LuFB9nDNfckoxb8COxKSFX";
```

You can obtain a license key for free from the Vuforia Developer website:

https://developer.vuforia.com/license-manager

The next two statements tell the Vuforia system to use the back-facing camera on the Android device and then it creates a VuforiaLocalizer using the initialization parameters that were set in the earlier statements.

```
parameters.cameraDirection = VuforiaLocalizer.CameraDirection.BACK;
this.vuforia = ClassFactory.createVuforiaLocalizer(parameters);
```

The next three statements load the Relic Recovery vision tracking dataset.

```
/**
 * Load the data set containing the VuMarks for Relic Recovery. There's only one trackable
 * in this data set: all three of the VuMarks in the game were created from this one template,
 * but differ in their instance id information.
 * @see VuMarkInstanceId
 */
VuforiaTrackables relicTrackables = this.vuforia.loadTrackablesFromAsset("RelicVuMark");
VuforiaTrackable relicTemplate = relicTrackables.get(0);
relicTemplate.setName("relicVuMarkTemplate"); // can help in debugging; otherwise not necessary
```

The op mode then prompts the user to push the start button to continue. When the op mode resumes after receiving a start command, it activates the relicTrackables object to begin looking for and identifying this set of VuMarks.

```
telemetry.addData(">", "Press Play to start");
telemetry.update();
waitForStart();

relicTrackables.activate();
```

The op mode then enters a while loop, which runs as long as the op mode is active (i.e., the user hasn't pushed the stop button).

```
while (opModeIsActive()) {
```

The op mode checks to see if one of the known VuMarks from the Relic Recovery dataset is visible. If it is visible, then it sends a telemetry message to indicate that the VuMark is visible.

If the VuMark associated with the “LEFT” goal is visible, the telemetry message will read “LEFT is visible”. Similarly, if the “CENTER” VuMark or the “RIGHT” VuMark is visible, the message will read “CENTER is visible” or “RIGHT is visible”.

```
/**
 * See if any of the instances of {@link relicTemplate} are currently visible.
 * {@link RelicRecoveryVuMark} is an enum which can have the following values:
 * UNKNOWN, LEFT, CENTER, and RIGHT. When a VuMark is visible, something other than
 * UNKNOWN will be returned by {@link RelicRecoveryVuMark#from(VuforiaTrackable)}.
 */
RelicRecoveryVuMark vuMark = RelicRecoveryVuMark.from(relicTemplate);
if (vuMark != RelicRecoveryVuMark.UNKNOWN) {

    /* Found an instance of the template. In the actual game, you will probably
     * loop until this condition occurs, then move on to act accordingly depending
     * on which VuMark was visible. */
    telemetry.addData("VuMark", "%s visible", vuMark);
```

If a known VuMark is visible, the example op mode then retrieves the pose information from the VuMark. The pose information provides the relative location and orientation of the camera with respect to the vision target. Note that these pose-related steps are NOT necessary to be able to identify a VuMark. The example shows these optional steps in case you are interested in knowing how to extract the pose information for a detected VuMark.

```
/* For fun, we also exhibit the navigational pose. In the Relic Recovery game,
 * it is perhaps unlikely that you will actually need to act on this pose information, but
 * we illustrate it nevertheless, for completeness. */
OpenGLMatrix pose = ((VuforiaTrackableDefaultListener)relicTemplate.getListener()).getPose();
telemetry.addData("Pose", format(pose));

/* We further illustrate how to decompose the pose into useful rotational and
 * translational components */
if (pose != null) {
    VectorF trans = pose.getTranslation();
    Orientation rot = Orientation.getOrientation(pose, AxesReference.EXTRINSIC, AxesOrder.XYZ, AngleUnit.DEGREES);

    // Extract the X, Y, and Z components of the offset of the target relative to the robot
    double tX = trans.get(0);
    double tY = trans.get(1);
    double tZ = trans.get(2);

    // Extract the rotational components of the target relative to the robot
    double rX = rot.firstAngle;
    double rY = rot.secondAngle;
    double rZ = rot.thirdAngle;
}
```

If a known VuMark is not visible, the op mode will let the user know.

7 Testing the Example VuMark Op Modes

If you’d like test the example VuMark op modes, you will need copies of the VuMark image targets. You can download the image targets for the 2017-2018 game from the FIRSTInspires.org website. Visit the FIRST Tech Challenge Game & Season Materials webpage for additional information:

https://www.firstinspires.org/resource-library/ftc/game-and-season-info